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Information Resources in Environmental Sciences: An Academic Viewpoint

The environment is just slightly larger than the earth and is comprised of the planet, with a gross weight of 5.88×10^{21} tons, a diameter of 7,900 miles, a surface of 197×10^{6} square miles, and a 10-mile thin skin, the troposphere, which is the site of clouds, rain, weather, and air pollution. From an anthropomorphic view, "spaceship earth" voyages through the solar system with a cargo of 3.6×10^{9} humans and an associated million odd species of plants and animals inhabiting the 57 million square miles of land surface and the 330 million cubic miles of lakes and oceans. In this context, the human environment has been defined as the aggregate of all social, biological, and physical or chemical factors which comprise the surroundings of man.

In dealing with so vast a subject matter, some limitations must be applied: the term "environmental science" has been defined as basic and applied inquiry about changes in environmental quality resulting from the activities of man.[1] For this discussion, the subject matter of environmental science is comprised of the chemical, physical, and biological changes in the environment through contamination or modification; the chemical nature and biological behavior of air, water, soil, food, and waste as they are affected by man's agricultural, industrial, and social activities; and the application of the natural sciences and technology together with the social sciences and law to control and improve environmental quality. Even under these limitations, the scope of environmental science demands a large share of the world's informational resources.

Deterioration of environmental quality started at an unknown date in antiquity when primitive man began to collect into villages and to utilize fire. However, environmental pollution has existed as a serious problem only since the industrial revolution which began with the invention of the steam engine by Watt in 1769 and the spinning jenny by Hargreaves in 1770. During the intervening 200 years, the exploitation of fossil fuels has provided the energy resources to support a world population increase from about 850 million to 3.6 billion. This rate of population growth can be supported only by increasing industrial and technological progress and it is now apparent that the more materialistic a society becomes, the greater the impact on the quality of the environment. U.S. society today has entered into an era picturesquely described by *Time* magazine as the "age of effluence."

Concern over environmental quality has become a major preoccupation in the United States only since the phenomenal industrial growth following World War II. The scientific and technological dimensions of environmental quality were first outlined in the 1965 President's Science Advisory Committee report, "Restoring the Quality of Our Environment,"[2] and the scope of the environmental quality movement as a popular crusade took shape with student involvement in 1969. The ultimate spread to global dimensions began with the June 1972 United Nations Conference in Stockholm on the human environment, where more than 1,400 participants from 113 countries approved a Declaration on the Human Environment and endorsed more than 100 proposals of an environmental action plan. (For a report on this conference see Anglemyer's paper in this volume.) Clearly, things will never be the same again and the world has embarked upon an environmental quality movement whose ultimate dimensions can scarcely be imagined. Environmental science is destined to play a decisive role in the human future.

ROLE OF ACADEMIC INSTITUTIONS

Academic institutions will play a very special role in the future study and evaluation of the problems of the quality of the total environment. These problems are often extremely complex and their definition generally lies beyond the scope of any single discipline. The development of significant information leading to feasible solutions for these problems will require the collaborative efforts of interdisciplinary teams of specialists working together in a problem-oriented atmosphere, each contributing his expertise to the multifaceted inspection of the problem. In effect we are describing a sort of super agricultural experiment station, that creation of the land grant college system which has so successfully helped develop the U.S. agricultural technology that the farmer who in 1850 fed four persons, now feeds forty. This very model for the mobilization of the resources of higher education has been recommended by Steinhart and Cherniack in *The Universities and Environmental Quality–Commitment to Problem Focused Education* in a report to the President's Environmental Quality Council. They recommended *"That the Federal Government assist in the formation at colleges and universities of Schools of the Human Environment."*[3]

Support and Funding of University Programs

The age of concern for environmental quality arrived at a time when academic institutions were experiencing extraordinary budgetary stringencies. The recession of the late 1960s affected not only federal and state funds but also private donors, and was accompanied by public disenchantment with the aims and goals of higher education. Thus the establishment of environmental institutes which promised to be large and costly was fraught with difficulties. There was great competition for already scarce funds between existing departments and colleges, and faculty and administrators were suspicious that then new institutes would preempt both areas of study and funds for growth. There was also a long faculty tradition of individual scholarly effort and consequent misunderstanding of multi-disciplinary and interdisciplinary modes of inquiry.

Fortunately for progress in the environmental age, certain farsighted sources of support materialized. University administrations have been unusually supportive both in the physical establishment of new environmental institutes and in providing the framework for their operation. A variety of new programs in federal agencies, private foundations, and state governments have provided at least the bare bones of support for the new institutes. The National Science Foundation has been responsive to the goals of "Restoring the Quality of Our Environment" and established its first program in this area under the IRRPOS program of 1970. This was the outgrowth of a 1968 amendment to the NSF charter to include applied research in its purview. The initial funding of the University of Illinois program for the study of lead in the total environment originated in this program. With increasing emphasis on problem-oriented research and long term societal needs, NSF created the RANN program in March 1971 to include the IRRPOS projects and other established NSF programs. About 75 percent of the $56 million available for RANN projects in 1972 was devoted to university programs. The RANN program encompasses four major divisions: (1) advanced technology applications–e.g., the earthquake engineering program of the University of Illinois; (2) environmental systems and resources–e.g., the program on environmental pollution by lead and other metals at the University of Illinois; (3) social systems and human resources; and (4) exploratory research and problem assessment.

Another major source of encouragement and funding has been the Environmental Quality Program of the Rockefeller Foundation. This was established in 1969 and has as its objective the establishment of major centers of expertise in key environmental areas at universities. The Rockefeller program has supported a program on nitrogen as an environmental determinant in the College of Agriculture at the University of Illinois; and a program on development of novel, selective, and nonpersistent insecticides.

The Illinois Institute for Environmental Quality, an arm of the state government, has many aims in common with the University of Illinois Environmental Studies Program and has supported a number of projects including preparation of monographs on *A Study of Environmental Pollution by Lead*[4] and *Chemistry and Biology of Trace Metals in the Environment.*[5]

The physical model developed by most universities to meet the challenges of environmental quality is an environmental studies institute, institute of environmental quality, or a similar title.[6] Most of the large land grant institutions in the U.S. have now formed such organizations. The Environmental Studies Institute of the University of Illinois, which has been underway since 1968, seems reasonably typical of these institutes, and its structure and aims will be described briefly. The institute encompasses the same scope of activities as its parent, the University of Illinois, i.e., teaching, research, and direct service to society. The mission of the institute "is to expand and transfer knowledge with increased emphasis on problem-solving uses of the knowledge . . . and included the extension of the educational experiences of the student through internship in industry or government and the dissemination of information gained from research to decision makers in industry and government."[7]

Research Components

The heart of the research program is a group of interdisciplinary and multidisciplinary task forces which will work on problems of broad social significance such as "environmental pollution by lead and other metals," "overcrowding of cities and its psychological and biological consequences," "nitrogen as an environmental determinant–technical, social, and economic considerations," "environmental consequences of the use of agricultural chemicals" and "world population evaluation and control."[8]

The mission of the task force on environmental pollution by lead and other metals in the environment provides an example of the research function of the Environmental Studies Institute. This task force has been supported by NSF grants totalling about $1,200,000 under the IRRPOS and RANN programs. The objective is to determine the movements and effects of heavy metals in the environment. Initial emphasis was placed on lead because of the enormous industrial usage in the U.S. Lead is presently consumed at the rate of 1.4 million tons annually in the United States with 19.5 percent as tetraethyl antiknock fluid burned in the engines of 105 million motor vehicles. This lead is emitted from the exhausts of these vehicles as an aerosol of lead chlorobromide and permeates the physical environment of all our cities and the lungs of all our urban dwellers. Cantarow and Trumper have described lead as the most important toxic hazard incident to the development of modern civilization.[9] Lead poisoning in young children in urban slums is a major source of brain damage, mental deficiency, and serious behavior problems[10] and it has been estimated that as many as 250,000 U.S. children have seriously elevated blood levels. In Chicago in 1966 there were 304 serious cases of childhood lead poisoning with five deaths. Recent surveys have shown substantial numbers of elevated blood levels in children in other Illinois cities.

Because of the increasing utilization of lead in industry and of tetraethyl lead in motor vehicles, which is increasing at about 5 percent per year, the lead levels in urban air are slowly increasing and ever larger amounts of lead are deposited in cities and along highways. Bellrose estimated that for all species of waterfowl in North America, the annual loss to lead poisoning, mostly from ingested shot, was between 2 and 3 percent of the population.[11] Thus the study of the total ecology of lead in the environment is an important facet of environmental sciences. Because of the key role of tetraethyl lead in the performance of the high compression gasoline engine and the sensitivity of catalytic smog prevention devices to lead poisoning, the removal of lead as a gasoline additive is a complex economic problem and it has been estimated that lead free gasoline will cost 2 to 4 cents more per gallon. The problem of lead in the environment therefore provides an exceptional opportunity to study the broad social interactions between economic, sociological, political, legal, and public health interrelations posed by society's attempt to correct a classic pollution problem.

The University of Illinois lead project is a truly interdisciplinary research effort involving seventy research workers in twelve departments. The basic emphasis is on mass transport in the terrestrial ecosystem and upon effects on plants and animals. A geographic area bounded by routes I-74 and U.S.45 and incorporating Brownfield Woods and the Saline Ditch is being used for input-output, for soil storage measurement, and for evaluation of plant and animal effects; physical measurements are also being made of this area. Extensive systems modeling and analysis is developing a complete model for transport of lead in the environment—where it goes, how much is located in various environmental components, evaluation of effects, prediction of future transports, and suggestion of effects that might occur due to changing the major sources of lead in the environment. The model will be evaluated by correlating it with the field data collected. The ultimate aim of the project is to gain understanding of the behavior of heavy metals in the environment, to evaluate alternatives for pollution control, and to develop an effective university organization for management of an interdisciplinary study of societal impact, to achieve both short-range goals and long-range contributions to human knowledge.

Educational Component

It is envisioned that the "on campus" educational program of the institute should include aspects of both graduate and undergraduate education. Formal courses should deal with the principles of environmental quality control, holistic concepts of environmental management, and social values applicable to the environment. Existing courses in other departments of the university will be used to the greatest extent commensurate with the interdisciplinary problem-oriented nature of the total educational problem in environmental studies.

Large scale emphasis is already being given to environmental education within the University of Illinois. On the Urbana-Champaign campus, 150 formal courses, out of a total of more than 5,500, deal specifically with environmental quality. These are presently conducted in the departments of agricultural economics, agronomy, anthropology, architecture, atmospheric sciences, biochemistry, biology, botany, business administration, chemistry, civil engineering, communications, computer science, economics, education, entomology, forestry, general engineering, geography, geology, industrial engineering, landscape architecture, law, library science, mechanical engineering, microbiology, physiology, political science, psychology, recreation and park administration, sociology, urban and regional planning, veterinary medicine, and zoology.

The Center for Human Ecology is incorporated into the Environmental Studies Institute and will become its educational arm. Existing courses in human ecology will be reinforced by others which will stress the holistic concepts of problem-solving. Existing courses in other departments will be crosslisted to develop sound and innovative educational programs. Students will be encouraged to participate in one or more task force programs as part of their educational experience. Every effort will be made to meet the programs of the institute with other developing curricula such as ecology, environmental engineering, and environmental law.

Public Service Component

The public service function of the Environmental Studies Institute is especially important because of the social relevance of its programs, and will be aimed at two levels: a consultative service to federal, state, or local governmental units, and a comprehensive program of public education and advice to citizens groups and individuals. It will include an editorial and publication staff whose function will be to translate research results into documents promoting the application of research results. Above all it will seek to build a three-way interchange between the information and research resources of the university, governmental agencies with their needs for expertise in the environmental science area, and the general public whose education and interpretive needs in the environmental quality area must become increasingly urgent because of the rapidly intensifying problems of human ecology.

REQUISITE LIBRARY RESOURCES

The magnitude of the environment, the urgency of environmental quality problems, and the extent of involvement of academic institutions in their study and solution, all pose challenges to the existing informational and library resources. It is axiomatic that academic institutions can neither serve their educational, research, and public service functions without extensive support from libraries, nor succeed in these functions without developing vast amounts of new information which libraries must hold, catalog, and make accessible to an ever-widening clientele. Although a thorough discussion of these problems is the total subject of this volume, a few remarks about specific problems are in order here. Again, observations will be restricted to the University of Illinois, Urbana-Champaign.

Research Resources

The interdisciplinary and multi-disciplinary modes of environmental sciences make extraordinary demands on the university research worker and his team and upon the libraries that serve them. The research and background information needed for successful environmental sciences studies such as air pollution, water pollution, noise pollution, pesticides and the environment, urban planning, land use allocation or human population control, covers many disciplines and demands access to books and journals from a wide variety of classical disciplines. These cannot be categorized readily into conventional library branches such as agriculture, biology, chemistry, engineering, geology, law, and medicine. The average research publication in *Environmental Sciences*

Areas of Emphasis	Total	Number Founded After 1965	Number Founded After 1970
Air pollution	8	5	0
Conservation	26	5	1
Ecology	11	1	3
Environmental design	4	2	2
Environmental engineering	9	2	2
Environmental health	11	2	1
Environmental law	5	0	5
Environmental sciences–general	24	7	13
Environmental toxicology	14	1	2
Marine pollution	7	1	1
Water pollution	10	1	0
Wildlife	8	2	1
Environmental sciences reviews	8	1	3
Environmental sciences abstracts, bibliographies, indices	20	4	7
Totals	165	34	41

Table 1. Areas of Emphasis, Numbers of Journals, and Dates of Origin for Periodicals in the Environmental Sciences

and Technology cites fourteen references and the average review article in *Advances in Environmental Science and Technology* cites seventy-nine references. These are largely journals and monographs with a considerable international flavor. Their variety and disciplinary diversity has to be seen to be believed. In addition, because of the very rapidly developing character of information in this area there is unusually heavy reliance upon reports from state and federal agencies, the National Academy of Sciences, and other paperback reports not commonly prized by librarians and not easily located in most libraries. The problem of collecting, preserving, and identifying this large source of information is a crucial one for environmental science library resources.

The data in table 1 are offered as an illustration of the problems involved in providing library resources in the environmental sciences and the problem of the reader in locating them. In the University of Illinois library, we have selected a list of 165 readily identifiable English-language periodicals relating to environmental sciences. These have been further classified into areas of emphasis such as air pollution, water pollution, conservation, ecology, toxicology, etc. These journals form the backbone of an environmental sciences collection and their number and diversity is substantial. The rate at which new periodicals are being published is interesting. Since the dawn of the environmental age in 1965, seventy-four new periodicals have appeared, representing 45 percent of the collection, and the rate seems to continue unabated. The information on beginning publication dates is indicative of the old well-established fields such as conservation, ecology, environmental health, environmental toxicology, marine and water pollution, and wildlife where the most important journals were established many years ago, as contrasted with new fields such as air pollution, environmental design, environmental engineering and environmental law. It is clear from this information that environmental sciences as a general subject has developed almost entirely since 1965 and is still developing very rapidly.

The number of journals, the rapid appearance of important new ones, and the steady increase in price index per volume, from $8.02 in 1967 to $11.66 in 1971[12] all highlight the problems of university libraries as they seek to serve the environmental sciences area.

Environmental Sciences Branch Libraries

As new areas of technological concentration develop, the problems of library classification and accessibility proliferate. Agricultural sciences libraries developed in land grant colleges in response to large scale demands for broad scale coverage of technological information relating to basic disciplines such as biology and chemistry together with developing applied sciences such as agronomy, entomology, forestry, horticulture, plant pathology, soil science and toxicology. The environmental sciences pose new dimensions for library resources at least an order of magnitude greater, involving economics, engineering, geography, law, sociology, and psychology among others. The germinal question therefore becomes: Is there need for a branch library in environmental sciences? From two viewpoints, that of the Environmental Studies Institute and that of the individual teacher and researcher in the environmental sciences, the answer is a qualified yes. From the viewpoint of the library scientist we are less certain. Table 2 shows information from the University of Illinois library on the location of files of twenty-five important journals which we have arbitrarily selected as important basics to environmental sciences. These are located in twelve branch libraries scattered over two square miles of campus and the geographical barrier obviously becomes an important one.

Periodicals	*Call Numbers*	*Location*
Air Quality Data	614.71	ENG, CPLA
Archives of Environmental Health	613.05	BIOL
Bulletin of Environmental Contamination and Toxicology	632.405	NHS, ENG
Environment and Behavior	309.2605	CPLA, MAP
Environmental Design and Research	711.01	CPLA
Environmental Engineering	613.105	ENG
Environmental Health Series: Air Pollution	614.71	ENG, CPLA
Environmental Health Series: Food Protection	614.3	HOME ECON
Environmental Health Series: Radiological Health	614.715	ENG, VET MED
Environmental Health Series: Urban & Industrial Health	614	ENG
Environmental Health Series: Water Supply and Pollution Control	614.772	ENG
Environmental Law	614.705	LAW, CPLA
Environmental Pollution	614.705	CHEM, BIOL
Environmental Science and Technology	614.705	ENG, CHEM, NHS GEOL SUR, AGR
Human Ecology	301.305	BIOL
J. of Air Pollution Control Assoc.	614.7105	ENG
J. of Environmental Education	301.305	PE
J. of Environ. Health	614.05	BIOL
J. of Environmental Quality	630.5	CPLA
J. of Environmental Sciences	620.5	ENG
J. on Human Ecology	301.305	BIOL
J. of Water Pollution Control Federation	628.05	ENG
Pesticides Monitoring Journal	614.7705	AGR
Water and Sewage Works	628	ENG, NHS
Water and Wastes Engineering	628.05	ENG

Table 2. Campus Location of 25 Important Periodicals in Environmental Sciences

THE FUTURE

Just as the vast preponderance of technical literature about agricultural sciences originates in land grant colleges, it seems reasonable to predict that these same institutions, together with their proliferating more youthful offspring—the other institutions of higher learning—will produce the major portion of the technical literature about environmental sciences. That information in this area will develop from its present trickle to a flood can scarcely be doubted. Most of the great problems of human ecology and environmental quality lie ahead and are illuminated in a provocative book *The Limits to Growth*[13] which should be required reading for all those with professional interests in the environmental sciences. This book presents the results of a study by the Club of Rome—"Project on the Predicament of Mankind"—utilizing a global model of system dynamics developed by Jay Forrester of M.I.T., to examine on a global scale the interrelations among the five basic factors that determine growth on earth: population, agricultural production, natural resources, industrial production, and pollution. The study concludes that unless an early global equilibrium is established among these factors (within twenty to fifty years), declining resources, the population explosion, food shortages, and pollution will contribute to a major collapse of civilization within the time span indicated. Many reasonable people and in particular technological enthusiasts may quarrel with the grim picture presented. Only those grossly ignorant of the implication of exponential growth in world population, in pollution, and in rate of resource depletion, will dismiss the conclusions as those of "irresponsible environmentalists." However, it cannot be doubted that early warning signals are already at hand. The nearly intolerable conditions in the inner cities of the megalopoli (e.g., the problems of refuse disposal in New York City), the ravages of air pollution in the Los Angeles Basin (e.g., the sudden death of several million ponderosa pines in the San Bernardino National Forest), the impending energy crisis in the United States (featured in *Scientific American, National Geographic, Saturday Review, Time, Newsweek*, etc.), and the starvation of millions in Bangla Desh—all these are but straws in the wind of the immense technological, social, and political revolution to be involved in the future of human ecology. The United States, which already consumes 44 percent of the world's coal, 33 percent of its petroleum, 63 percent of its natural gas, 28 percent of its iron, 38 percent of its nickel, 42 percent of its aluminum, 33 percent of its copper, 25 percent of its lead, 24 percent of its mercury, and about 40 percent of its available electric power—to service only 6 percent of the total global population—cannot escape tremendous technological changes as the irresistible trend toward global equilibrium continues. Information resources in the environmental sciences are crucial to both the education of the citizens, to the problems lying just ahead, and to the support of the technological revolution in the offing.

Year	*Gross National Product (billions of dollars)*	*Books Published*
1950	$ 284.8	11,022
1955	398.0	12,589
1960	503.7	15,012
1965	684.9	28,595
1969	931.4	29,579
1970	976.5	36,071

Source: U.S. Department of Commerce, *Statistical Abstract*, 1971.

Table 3. Gross National Product of the United States and the Production of Books

Effects on Information Resources

There is an interesting and perhaps predictable relation between gross national product and publication of books and journals. In the U.S. the parallel is astonishingly exact, both quantities following almost identical curves (table 3). This relationship is exact enough and has the appropriate rationality to permit some interesting extrapolations. The GNP in 1970 was $976.5 billion and the average price of a hardcover book was $11.66.[14] The ratio of these two interdependent values suggests that each hardcover book is based upon $27 million of GNP. In 1970, 13,448 of the 36,071 books published (37 percent) were in areas pertaining to environmental sciences. Extrapolations of the U.S. GNP to 2000 A.D. suggest a value of $1,920 billion or approximately double the 1970 value and at least a consequent doubling of the number of relevant technological books to about 27,000 yearly.

Another useful yardstick for prediction of the growth of information resources in the environmental sciences is the extent to which capital funds will be directed toward improving environmental quality. Two figures are available: the recent action of Congress in appropriating $24.6 billion, over President Nixon's veto, for the Clean Water Act which aims to end water pollution by 1985, and the estimate by the U.S. Council on Environmental Quality of $105 billion to be spent by 1975 for a partial clean-up of American air, water and solid waste pollution.[15] At the previously established ratio of $27 million GNP per book, the expenditure of $105 billion should lead to the production of approximately 4,000 new books by 1975 directly related to the subject matter of environmental sciences. The attendant array of journal volumes, reports of governmental agencies, etc., should boggle the collective minds of library scientists. We have already suggested that academic institutions will produce a substantial majority of this flood of information and will be absolutely dependent upon university libraries for resource support in this burgeoning area. The challenge to university librarians is weighty, direct, and immediately at hand.

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